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MILLISECOND-TIME-SCALE ATMOSPHERIC LIGHT PULSES INDUCED BY SOLAR ACTIVITY

H. OGELMAN
A. FISHER
D. BERTSCH

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GSFC — GODDARD SPACE FLIGHT CENTER
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H. Ögelman, A. Fisher
Physics Department, Middle East Technical University, Ankara, Turkey

and

D. Bertsch
Goddard Space Flight Center, Greenbelt, Md.
U.S.A.

ABSTRACT

A wide-angle photomultiplier system designed to detect fluorescence light emission induced by bursts of energetic photons of cosmic origin has been in operation for over two years. During this time a class of fast atmospheric pulsations (FAP) of millisecond time scale has been discovered. The physical extent of the atmosphere involved in this emission is around 100 km. Nights with very high FAP rates appear to be correlated with strong solar activity. It is believed that these events are caused by instabilities associated with particles stored in the magnetosphere.

1. Introduction:

Theoretical work on the acceleration of cosmic rays by supernovae has led Colgate[1], to predict that a sub-millisecond time scale burst of energetic photons should accompany the shock wave that accelerates the cosmic rays. A possible method of investigating this pulse with ground based detectors is to search for the fluorescence light produced in the atmosphere when the photon pulse is absorbed. Such a system has been in operation since September 1968. Initial results disclosed a variety of pulsed light-producing phenomena which constituted a recognizable background to the experiment. In an attempt to completely eliminate the local events, two identical detectors were operated at separations of 175 km and 3300 km and accurate arrival times of events were recorded. A pulse originating outside the solar system should illuminate the separated stations almost identically whereas other local phenomena would either be absent in one station or the responses of the two station would be quite different.

The runs with 175 km spacing revealed a class of one millisecond time-scale events which were coincident in the two stations about 5% of the time. These events, designated as Fast Atmospheric Pulsations (FAP), showed a very consistent pulse shape from night to night and also their nightly rate seemed to be correlated with strong solar activity. Although these events are definitely not associated with supernovae, it seems worthwhile to investigate their nature since we are facing a previously unknown form of atmospheric disturbance.

It is already known that micropulsations in the earth's magnetic field have frequency components as high as 100 Hz and that these oscillations are correlated with light emission in auroral zones and solar activity[2]. However, the FAP light frequency structure extends to 10 KHz and to low geomagnetic latitudes as well which is outside the range of previous experiments.

With the purpose of investigating the geomagnetic nature of these events a single station has been operated in Ankara, Turkey (magnetic latitude $\Phi = 36.7^{\circ}$, magnetic longitude $\Lambda = 110.5^{\circ}$ and having an ℓ value of 1.56) since June 1970. The following is a description and discussion of these measurements.

2. The Experiment:

A station consists of three 12-inch photomultiplier tubes with collimators that restrict their opening angles to 70° from vertical and provide a response function with FWHM being 86°. Two of the tubes have wide transmission filters covering the atmospheric fluorescence region between 3200 Å and 4300 Å and are denoted by V (violet). The third tube has a filter with a low wavelength cutoff of about 4300 Å and is denoted by Y (yellow). The response characteristics of these tubes including the filter and atmospheric transmission are shown in Fig. 1. During most of the running time the two violet units were tilted 30° from zenith in opposite directions while the yellow unit was pointed toward zenith. The anode pulses after an integration of 50 microseconds are fed into preamp-discriminators. The outputs of the discriminators are connected to a coincidence unit where the

simultaneous outputs from tubes denote an event. When this criterion is met, the oscilloscope is triggered and the output of three tubes are recorded on 35 mm film. The entire system is turned on and off automatically by a programmed timer that is set for moonless nighttime operation. The triggering sensitivity of the apparatus is about 10^2 photons/cm^2-50μ-sec[3].

Records of each observing station reveal similar categories of local events which are distinctly different from the expected supernova type events. The majority of these may be classified as: 1) Cerenkov light from air showers, 2) lightning, 3) pulses with rise-time of 200 microseconds and falltime of 400 microseconds denoted as "A" events, 4) FAP pulses.

Cerenkov events, because they are produced in a localized region have characteristically short time scales. Their identity has further been established by observing charged particles in coincidence with the Cerenkov light. Lightning events have a relatively long time scale and show considerable pulse structure. Events of this type are recognizable and correlate with local observations of lightning. The two remaining types of events, the "A" and "FAP" events have not previously been encountered in the literature. During good weather conditions the dominant cause of triggers are "A" events, reaching rates as high as 50 per hour on certain nights. Diurnal variation of "A" event rate shows a strong peaking towards 20 UT (22 local time). It is interesting to note that the world average of the earth's electric field and lightning rate also peak at the same

universal time[4]. The most likely origin of these events is in the atmospheric electric current systems. They appear predominantly in clear weather conditions and seem to be distinctly different from ordinary lightning.

First notice as coincident pulses in the 175 km apart two station system, the FAP events show a very consistent pulse shape as shown in Fig. 2. The general features of the pulses are:

1. The typical duration of activity is one millisecond long.
2. The activity consists of a 10 KHz damped oscillation in the Y tube. V tubes show a pulse with rise time of 200 microseconds and fall time of 400 microseconds without the 10 KHz activity.
3. The Y tube usually starts with a negative pulse (i.e. darkening sky). As the low frequency time constant of the system is 0.1 second, this would imply a slow brightening of the sky on this time scale followed by rapid fluctuations of light.
4. The typical energy incident on the photomultiplier is about 4×10^{-8}ergs/cm^2 in the Y tube and 1.5×10^{-8}ergs/cm^2 in the V tube. However, the unobserved slow rising portion of the pulse may contain the bulk of the energy.

The fact that 5% of the events observed over a 175 km baseline are coincident implies that the disturbance covers an area of about 100 km in radius on the surface of the earth. The total light energy on this surface is about 1.6×10^7 ergs. If we assume that this light is produced by energetic particles ionizing the upper atmosphere and that

the fluorescence efficiency is around $5x10^{-3}$ then the total energy dissipated in the atmosphere is about $3x10^{9}$ ergs. Although over 1400 hours of running time have been accumulated to date, only approximately 500 hours of data taken in the Ankara, Turkey station, covering the period from June 1970 to June 1971 has been systematically analyzed. The diurnal distribution of these FAP events as a function of time is shown in Fig. 3. As can be inferred from the graph, there seems to be a minimum toward midnight with increasing activity towards sunrise and sunset. It was further noticed that the arrival times of the FAP events showed some regularity. In Fig. 4 we have plotted a histogram of arrival time differences of the events for the nights of Oct. 26, 1970; Dec. 7, 1970 and Jan. 28, 1971 where the FAP rate was higher than usual. If the events were coming randomly this histogram should be an exponentially decaying curve with a time constant of about 6 minutes. However the broad peak centered on 2.5 minutes indicate a preferred repetition rate with this period.

Figure 5 shows a plot of the average nightly FAP rate plotted according to the days in solar rotation interval. The sudden commencements of the magnetic field during or within one day of the "on times" of the detector are indicated as well (up to June 1, 1971). The striking feature is the 27 day repetition of the enhanced FAP rate that starts on Jan. 26, 1971 following a big solar flare and appears for three consecutive rotations. The sudden commencements also accompany these FAP rate enhancements.

In addition to the 27 day interval, the FAP events seem to involve 3 basic frequency components:

1. The 10 KHz damped oscillations in the event, 2. the 1 millisecond (1 KHz) rise and fall time for the event, 3. The 2.5 min favored repetition interval.

Among the known natural electromagnetic field fluctuations, upper atmosphere ELF (extra low frequency) signals cover roughly the range of the 1-10 KHz features. Since ELF signals are associated with the earth-ionosphere wave guide it is quite possible that we are also dealing with similar phenomena in the case of FAP events. The 2.5 min. interval calls attention to the periodicities observed in geomagnetic micropulsations.[2] A likely cause of these events is the interaction of solar plasma with the magnetosphere whereby particles are dumped into the ionosphere and excite reasonant modes in the earth-ionosphere cavity.

Systematic measurements of this new phenomena in a variety of locations will aid in an understanding of the complicated geomagnetic effects.

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REFERENCES:

1. Colgate, S. A., Can. J. Phys. 46, S476, 1968.

2. Campbell, W. H., "Physics of Geomagnetic Phenomena" Ed. by S. Matsushita and W. H. Campbell (Academic Press, New York and London), Vol. II, 821, 1967.

3. Ogelman, H. and Bertsch, D., Acta Phys. Acad. Sci. Hung. 29, Suppl. 1, 35, 1970.

4. Whipple, F. J. W., and Scrase, F. J., Geophys. Mem., London, 68, 1, 1936

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Fig. 1. Spectral response of the two-color photomultiplier system including filter and atmospheric transmission shown as a function of wavelength.

2. A typical FAP event.

3. Diurnal distribution of FAP rate averaged over June 22, 1970 to May 31, 1971. Local time is UT+2 hours.

4. Arrival time difference, distribution for the FAP events of Oct. 26, 1970; Dec. 7, 1970 and Jan. 28, 1971.

5. Average nightly FAP rate plotted according to the days in Solar rotation interval. On the vertical scale the distance between two lines represents a rate of 14 events per hour. Periods with no events correspond to unfavorable observing conditions due to weather and excessive moonlight. (▲ denotes sudden commencements)

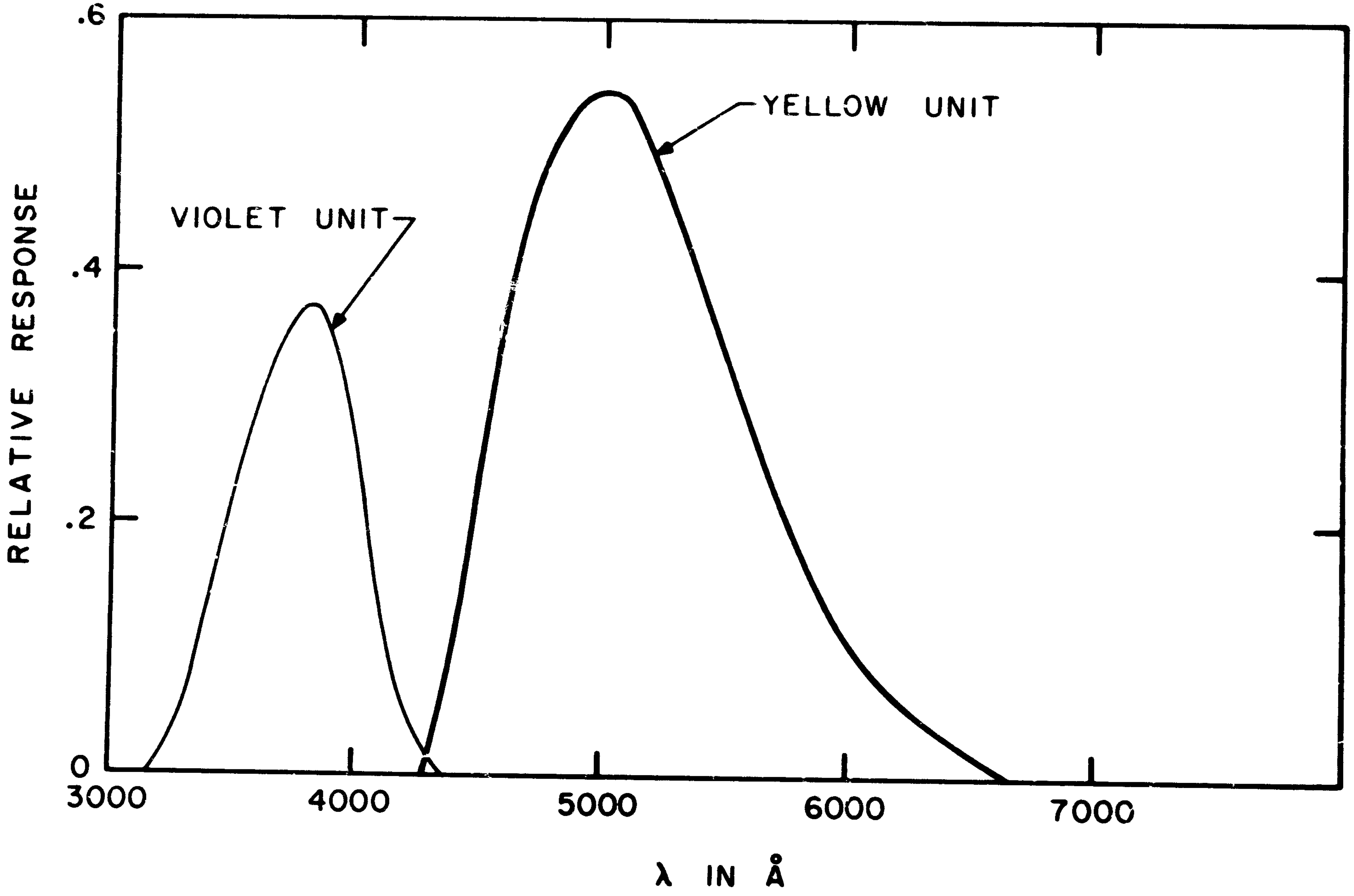

.6
.4
.2
0
3000
4000
5000
6000
7000
RELATIVE RESPONSE
λ IN Å
VIOLET UNIT
YELLOW UNIT

Fig. 1

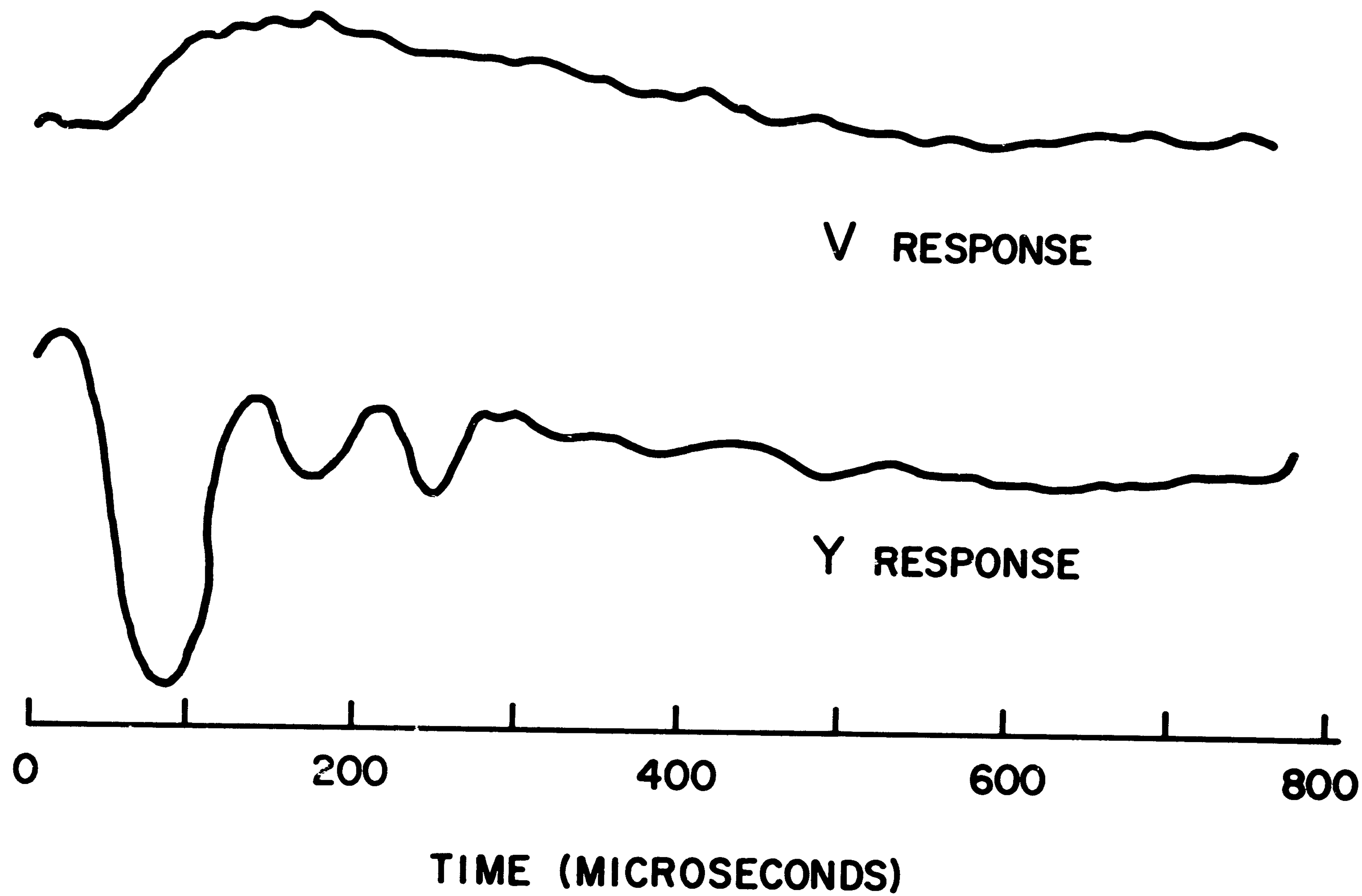


Fig. 2

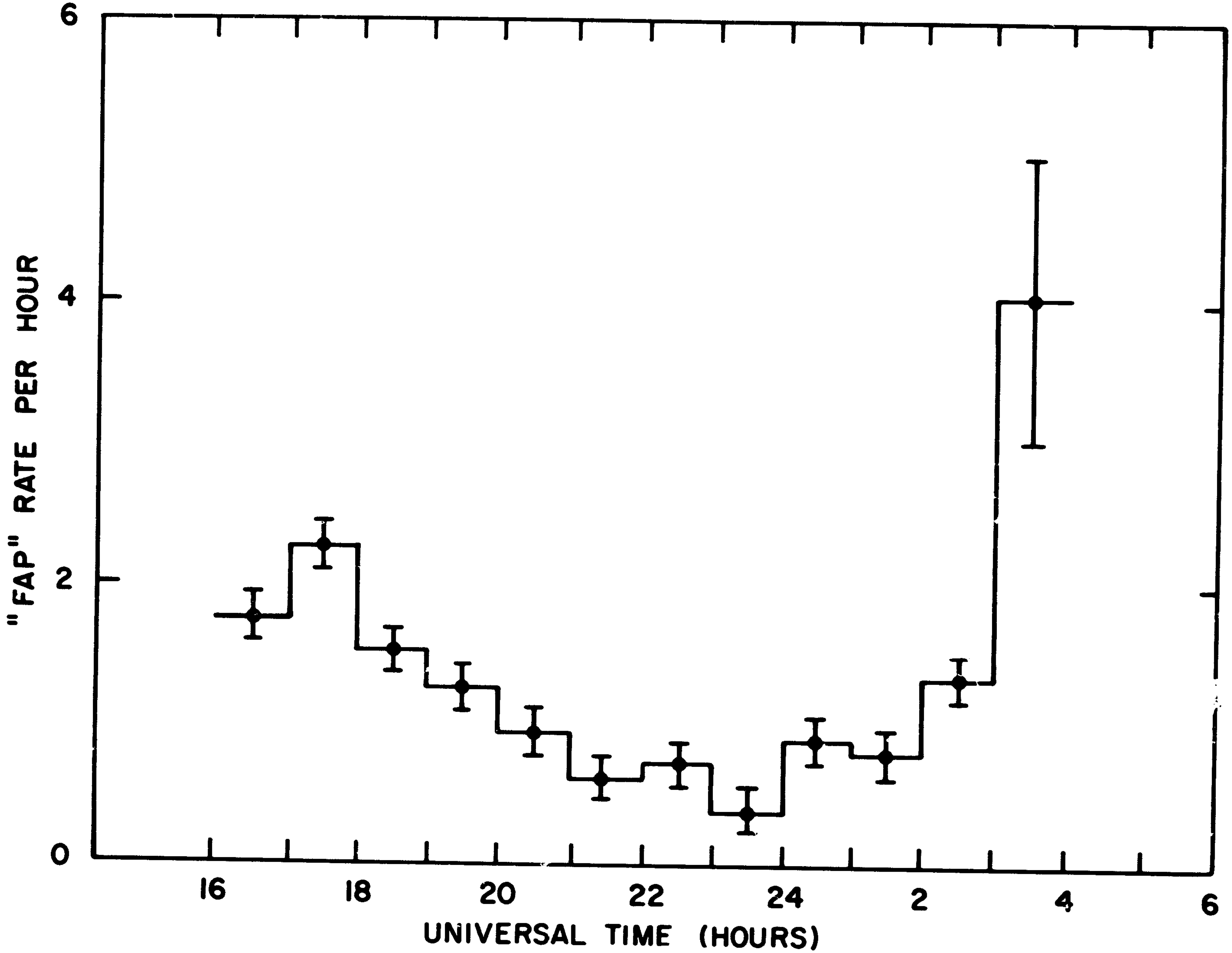
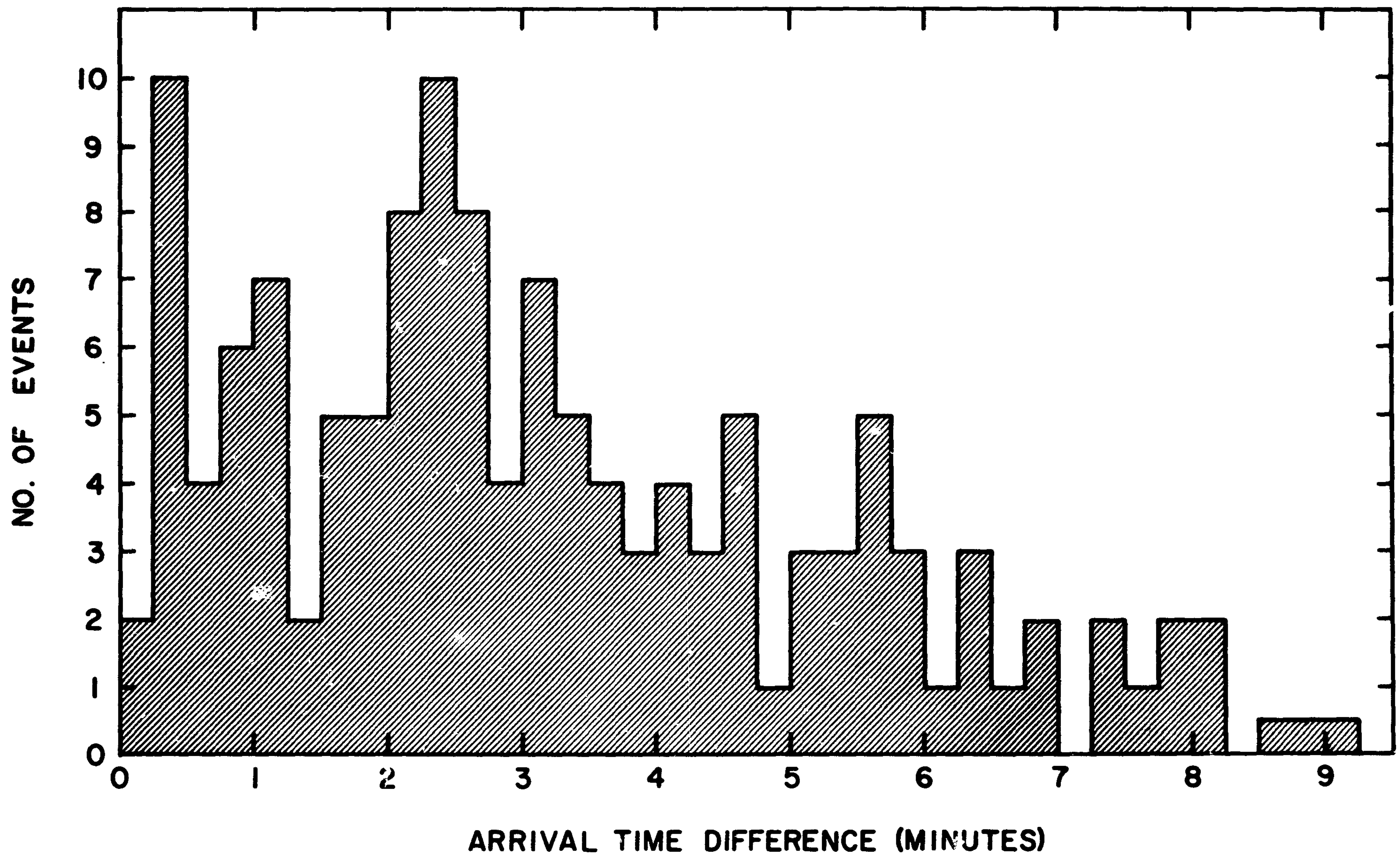
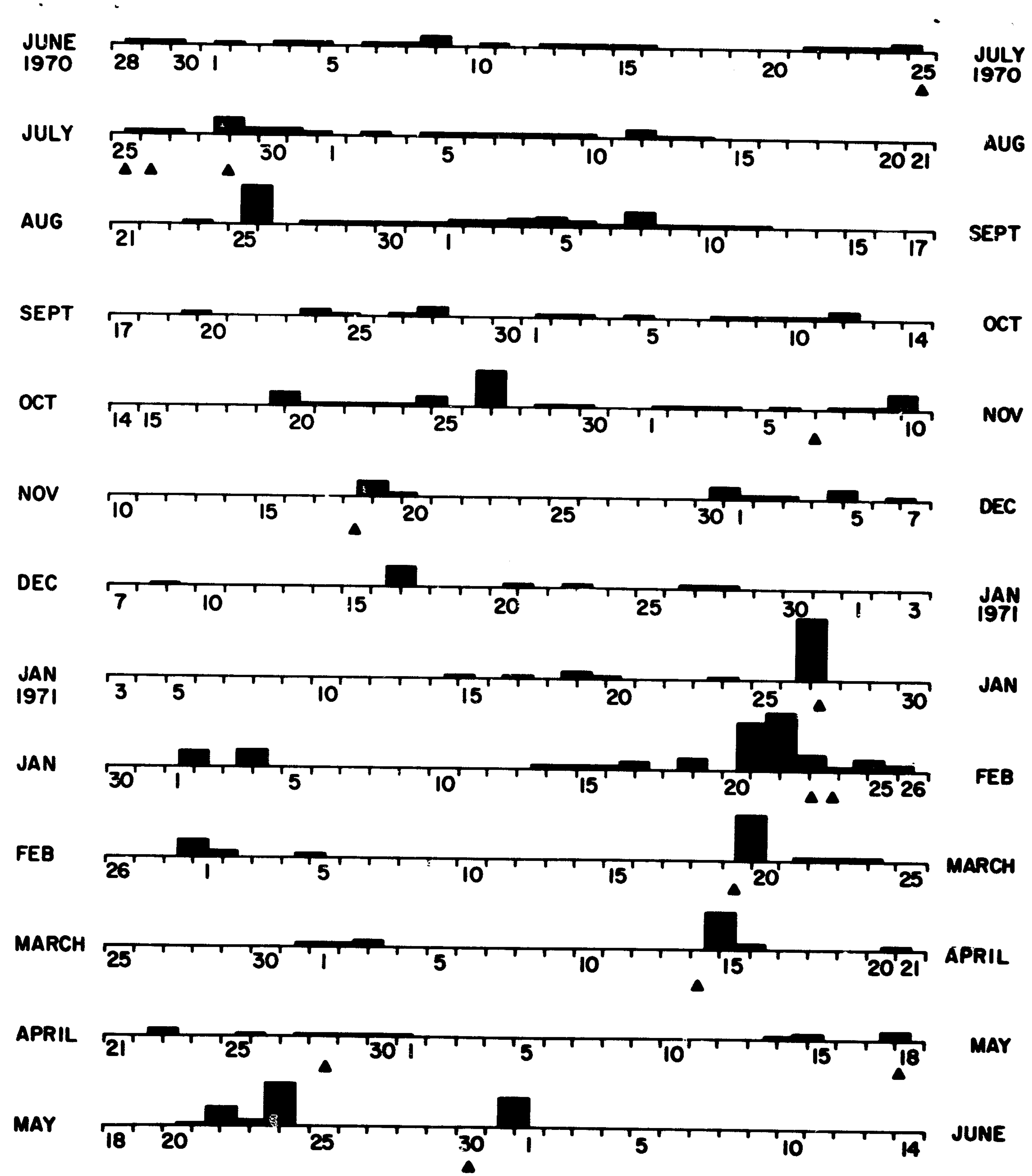


Fig. 3



NO. OF EVENTS
0
1
2
3
4
5
6
7
8
9
10
ARRIVAL TIME DIFFERENCE (MINUTES)

Fig. 4



JUNE 1970
JULY 1970
JULY
AUG
SEPT
OCT
NOV
DEC
JAN 1971
JAN
FEB
MARCH
APRIL
MAY
JUNE

Fig. 5